Hydrologic Model Manager

Short Name	FEQ
Long Name	Full Equations Model
Description	
Model Type	One-dimensional unsteady flow in open channels and through control structures. Flow and elevation are simulated through looped or dendritic networks. A wide variety of hydraulic control structures can be incorporated in the simulation by applying the accompanying Full Equations Utilities Model (FEQUTL).
Model Objectives	FEQ and FEQUTL are used for hydraulic design and analysis, stormwater management, urban planning, and flood-plain mapping. FEQ has been approved by FEMA for use in the National Flood Insurance Program (NFIP).
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Model Structure	FEQ simulates flow in a stream system by solving the full, dynamic equations of motion for one-dimensional unsteady flow in open channels and through control structures. The structure of the program is designed to follow the structure of a stream system while providing maximum generality and flexibility of description. A stream system that is simulated with FEQ is subdivided into three broad classes of flow paths: (1) stream reaches (branches), (2) parts of the stream system for which complete information on flow and depth are not required (dummy branches), and (3) level-pool reservoirs. These components are connected by special features or hydraulic control structures, such as junctions, bridges, culverts, dams, waterfalls, spillways, weirs, side weirs, pumps, and others. The hydraulic characteristics of channel cross sections and special features are stored in function tables calculated by the companion program FEQUTL. FEQ can interpolate hydraulic properties of cross sections between measured sections. FEQ can be applied in the simulation of a wide range of stream configurations (including loops), lateral inflow conditions, and special features. Boundary conditions can be water-surface stage, discharge, or the stage-discharge relationship at a node. Wind stress terms are supported. The effects of lateral inflows can also be simulated in FEQ when given local runoff intensity data.

	In FEQ, the principles of conservation of mass and conservation of momentum are used to calculate the flow and depth throughout the stream system resulting from known initial and boundary conditions with an implicit finite-difference approximation. FEQUTL is used to compute the hydraulic properties of various structures, each with its own computational theory.
Interception	
Groundwater	
Snowmelt	
Precipitation	
Evapo-transpiration	
Infiltration	
Model Paramters	The effect of channel friction on flow is simulated with Manning's n roughness coefficient. The routines in FEQUTL for determining discharge require discharge coeffecients for orifices or weirs and other estimates of head loss resulting from sudden changes in effective flow areas, sharp corners, pumps, etc. These are often determined from standard engineering handbooks or physical modeling.
Spatial Scale	Stream systems may range from small streams or laboratory models to large rivers. The de Saint-Venant equations must be applicable with the basic assumptions that the velocity over the cross section is uniform with a horizontal surface, the streamline curvature is small and vertical accelerations are negligible (hydrostatic pressure), the effects of boundary friction and turbulence can be simulated by resistance laws utilized for steady flow, and the average channel bed slope is small enough to approximate the cosine of the slope angle by 1.
Temporal Scale	The maximum time step for simulation may range from fractional seconds to days and can be set by the user. FEQ will automatically reduce the time step to a user-set minimum as required for convergence.
Input Requirements	FEQ reads an input file that contains specifications of run control parameters, an encoding of the stream schematic, and initial conditions. This file can contain boundary-condition tables and function tables for special features, or it can identify additional files that contain the information. FEQUTL computes function tables from specifications and data provided in input files. FEQUTL can read HEC-2 and WSPRO cross-section input data and calculate cross-section function tables for use in FEQ simulation. Function tables for bridges are computed using the program WSPRO to compute a suite of upstream and downstream water-surface elevations. FEQUTL can create input files for WSPRO and convert tables output by WSPRO into a format suitable for FEQ.

Computer Requirements	FEQ is a written in Fortran 77 and Fortran 90, and is currently compiled for UNIX and PC. The source code is available for porting to any other platform.
Model Output	FEQ outputs files that can be accessed by the GENeration and analysis of model simulation SCeNarios (GENSCN) software for plotting hydrographs and function tables, producing statistics, animating profiles and flow threshholds. Other binary and ASCII output formats are available, including HECDSS.
Parameter Estimatn Model Calibrtn	Model calibration is achieved manually, although automatic interpolation of cross sections is available to complete a convergence analysis.
Model Testing Verification	FEQ has been applied and compared to measured data by the U.S. Geological Survey in cooperation with the Illinois Department of Natural Resources, and Du Page County, Illinois to simulate (1) unsteady flow in laboratory channels, (2) unsteady flow in a large stream system (Fox River in northeastern Illinois) with multiple low-head dams (3) unsteady flow in a small stream system (Spring Brook in northeastern Illinois) with culverts and overbank flow. The results of these tests are reported in Franz and Melching (1997a), Turner and Ishii (1998) and Turner and others (1996). The USGS has used FEQ in other applications also described in references listed at http://il.water.usgs.gov/proj/feq/feqbib.html.
Model Sensitivity	It is necessary to maintain a small baseflow in the channels throughout a simulation. A Preissman slot may be utilized to minimize the water-surface elevation.
Model Reliabiity	FEQ has been accepted by FEMA for the National Flood Insurance Program (NFIP) and has been successfully calibrated and applied as well as tested and verified for a wide range of cases. FEQ is highly robust because of its implicit formulation and efficient matrix solver.
Model Application	FEQ has been applied nationally and internationally for hydraulic design, urban stormwater drainage analysis, watershed planning, dam safety analysis, and flood-damage reduction. It has been applied for flood-plain mapping and real-time flood warning simulation. Selected references are available at http://il.water.usgs.gov/proj/feq/feqbib.html
Documentation	FEQ and FEQUTL have been documented in a series of reports by the U.S. Geological Survey. These reports may be downloaded in PDF or viewed online at the USGS FEQ project web site http://il.water.usgs.gov/proj/feq/ Franz, D.D., 1982, Tabular representation of cross-sectional elements: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 108, no. 10, p. 1070-1081. Franz, D.D., and Melching, C.S., 1997, Full Equations (FEQ) model for the solution of the full, dynamic equations of motion for one-dimensional unsteady flow in open channels and through control structures: U.S. Geological Survey Water-Resources Investigations Report 96-4240, 258 p.

	Franz, D.D., and Melching, C.S., 1997, Approximating the hydraulic properties of open channels and control structures, during unsteady flow using the Full Equations Utility (FEQUTL) program: U.S. Geological Survey Water-Resources Investigations Report, 97-4037, 205 p.
Other Comments	Basic and advanced FEQ courses are co-sponsored by ASCE, the U.S. Geological Survey, and Du Page County, Illinois and are taught by the model author, Dr. Delbert Franz. Information on recent or upcoming courses may be found at the USGS FEQ project web site http://il.water.usgs.gov/proj/feq/
Date of Submission	8/10/1999 2:14:10 PM
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